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A Study of Demoulding Force Prediction Applied to Periodic Mould Surface Profiles

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A STUDY OF DEMOULDING FORCE PREDICTION APPLIED TO PERIODIC MOULD SURFACE PROFILES

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For further details and to access the full paper please refer to the conference proceedings.

-Kevin D. Delaney,
26May2010

A STUDY OF DEMOULDING FORCE PREDICTION APPLIED TO PERIODIC MOULD SURFACE PROFILES

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Dr. G. Bissacco, University of Padova.

Dr. D. Kennedy, Dublin Institute of Technology.

Aim of this research

Can we predict demoulding forces if we know:

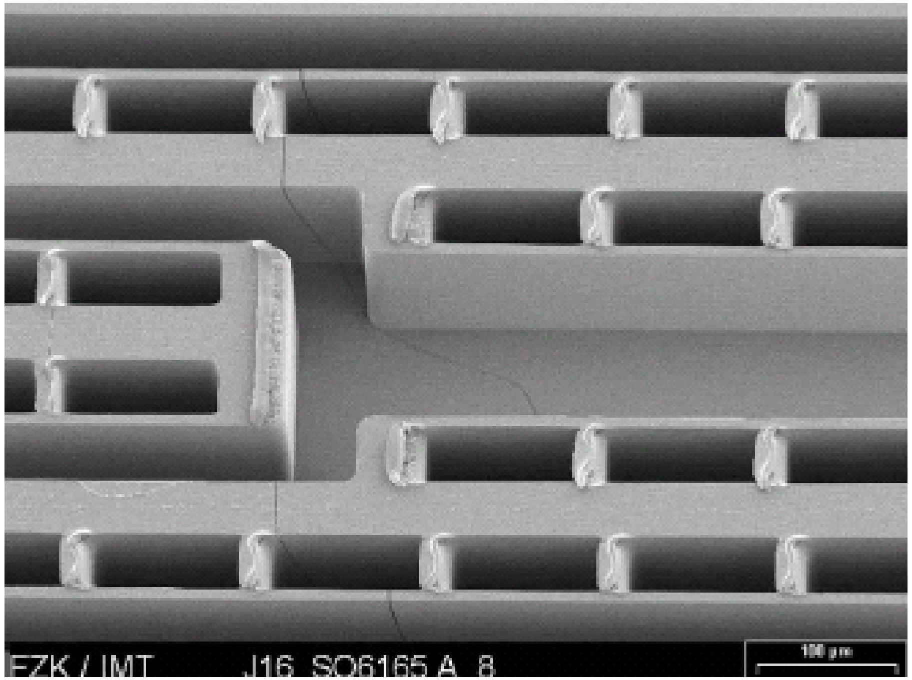
- Parameters used to fabricate the replication tool
- Replication process parameters
- Details of the mould and part materials

?

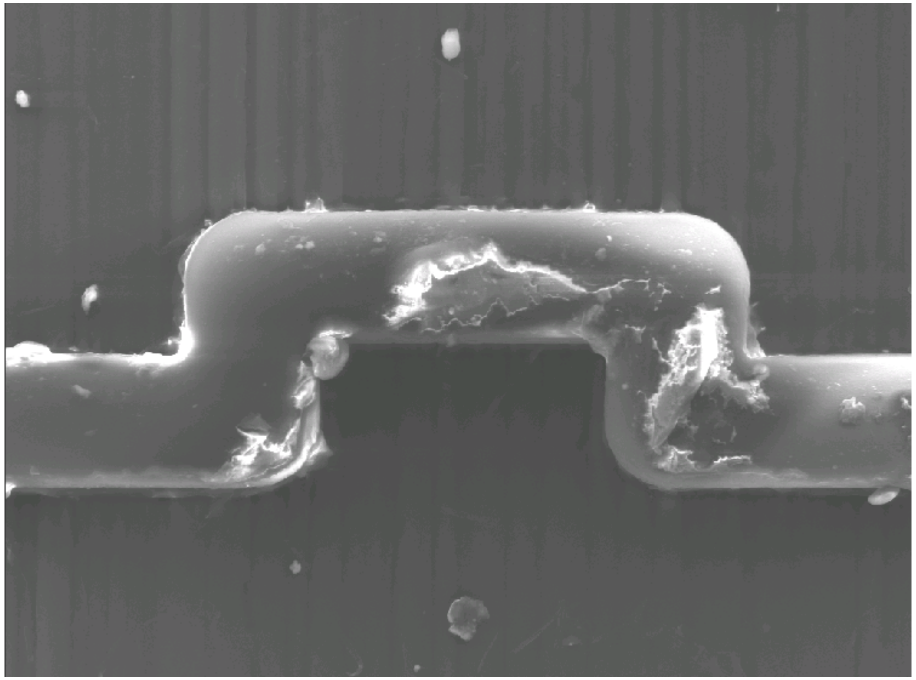
Presentation Outline

- The problem of demoulding force
- Demoulding force modeling
- Note regarding replication tool surfaces
- Adapting Colton et al model to periodic profiles
- Validation of the model

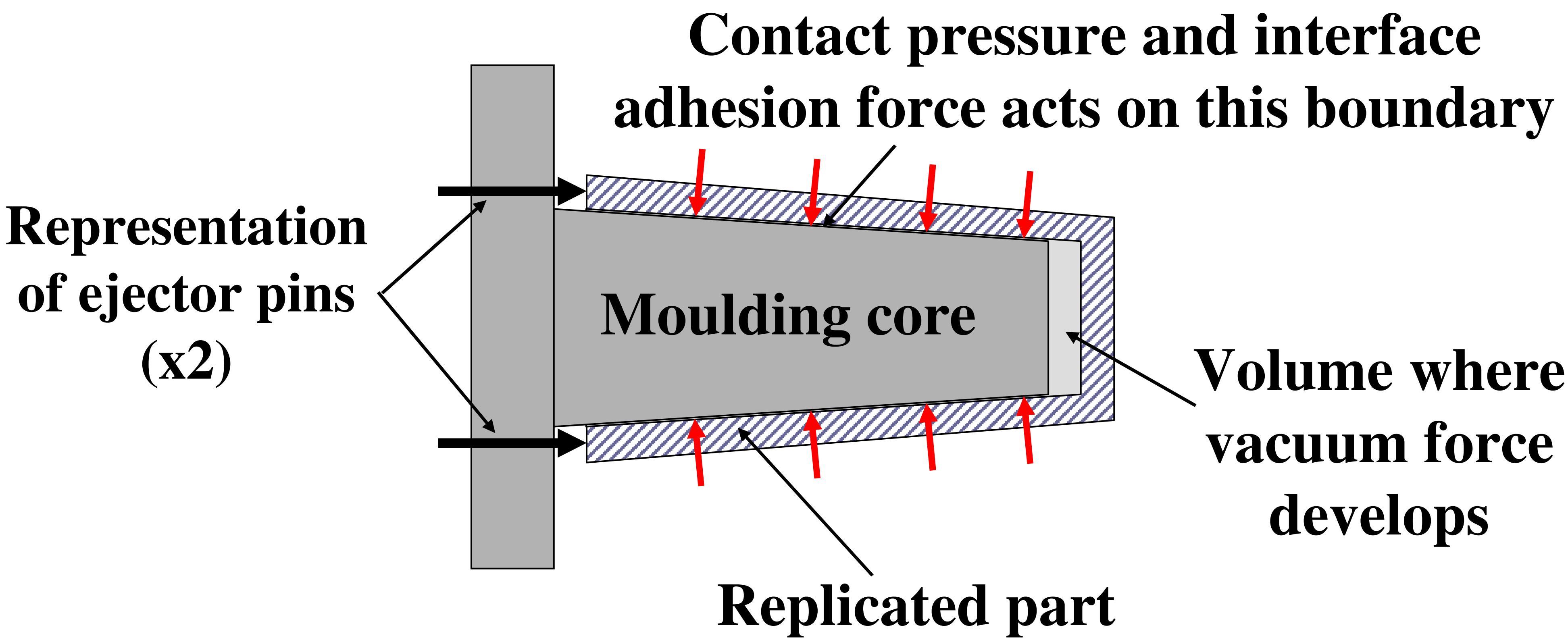
Examples of the problem at micro scale



[Worgull et al]



Contributors to demoulding force



Demoulding force modelling

Area of contact (A_c)

Coefficient of friction (μ)

Normal contact pressure (P_A)

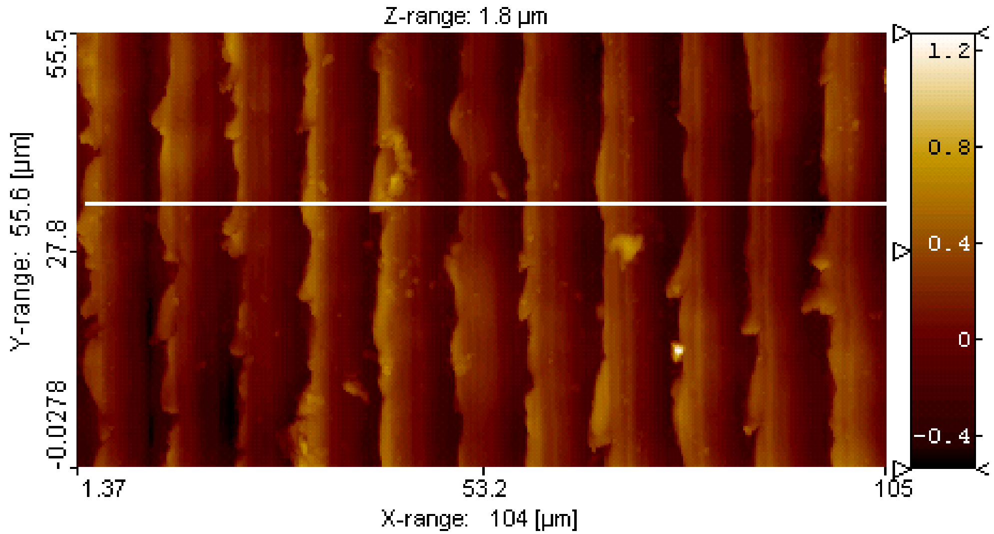
Demoulding force model

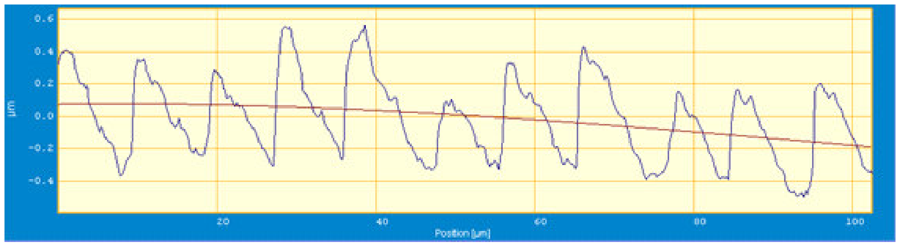
$$F_R = \mu \times P_A \times A_C$$

Release force (F_R) prediction

Note regarding replication tool surfaces

- Replication tools are mainly produced by mechanical processes with an inherent surface roughness.
- Even at the micro scale asperities and burrs cause interlocking which results in demoulding problems.
- During demoulding either the part or tool have to deform to slide over each other.

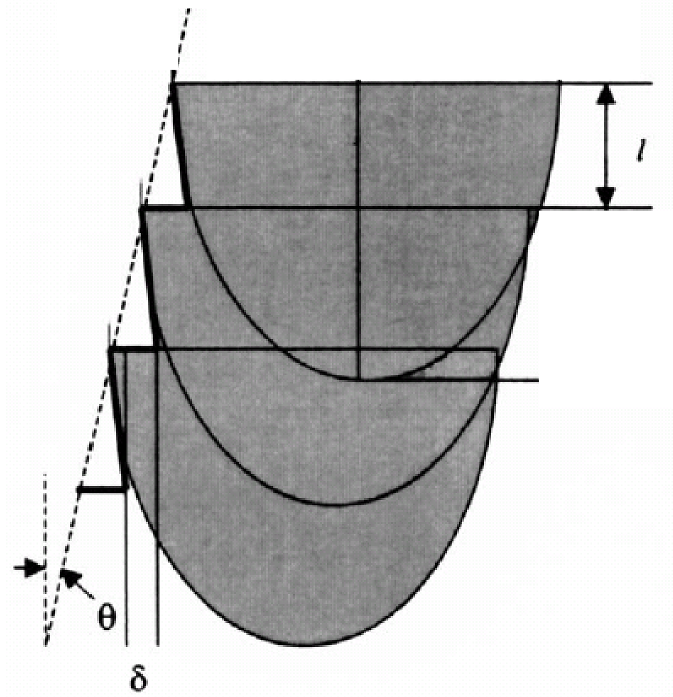




Micro replication tool and surface profile

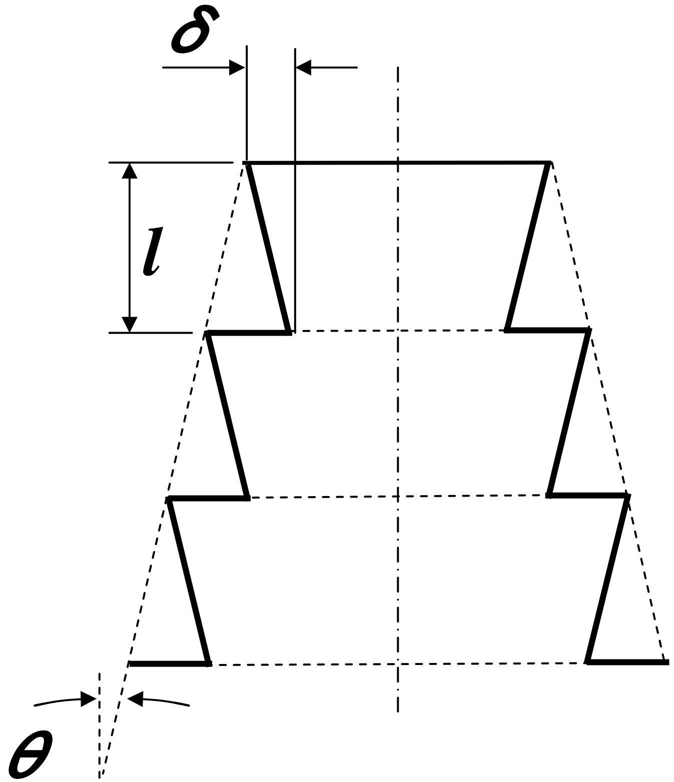
The Colton et al model - 1

- Developed for stereo-lithographic tools
- Stair-like surface profile



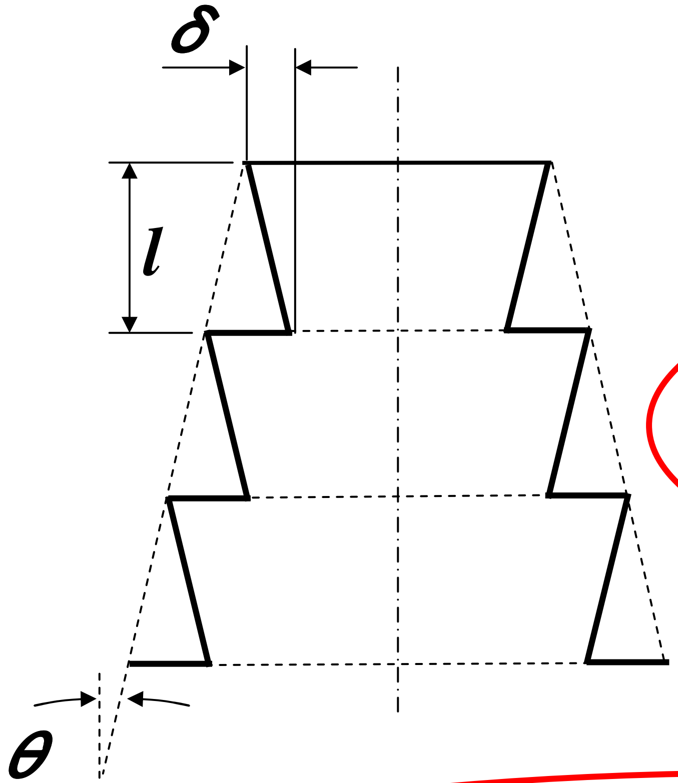
$$F_{ej} = F_{fric,therm} + F_{def,stair}$$

The Colton et al model - 2



$$\mu_{eq} = \mu + fn(\delta, l, \theta, Temperature, materials)$$

The Colton et al model - 2



Additional μ contribution due to surface roughness

$$\mu_{eq} = \mu + fn(\delta, l, \theta, Temperature, materials)$$

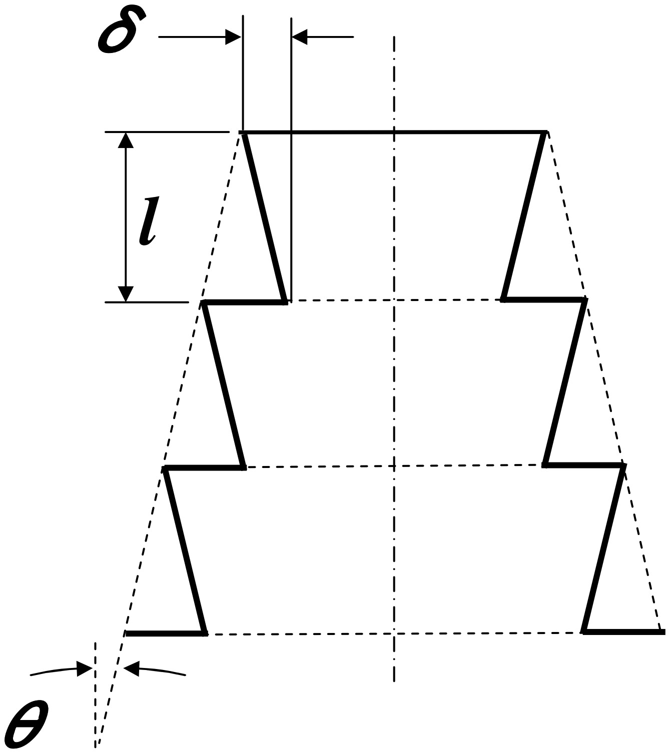
The Colton et al model - 3

- The Colton et al model has already been applied.
- It tries to explicitly capture how the coefficient of friction varies with surface roughness.
- We can benefit from adapting it for other periodic surfaces.

Adapting the Colton et al model

1. Analogy between stereolithographic and periodic (turned) surface
2. Surface simulation and analysis for verification
3. Model Implementation
4. Model Validation using published data
5. Model Robustness study

Analogy between stereolithographic and periodic (turned) surface - 1

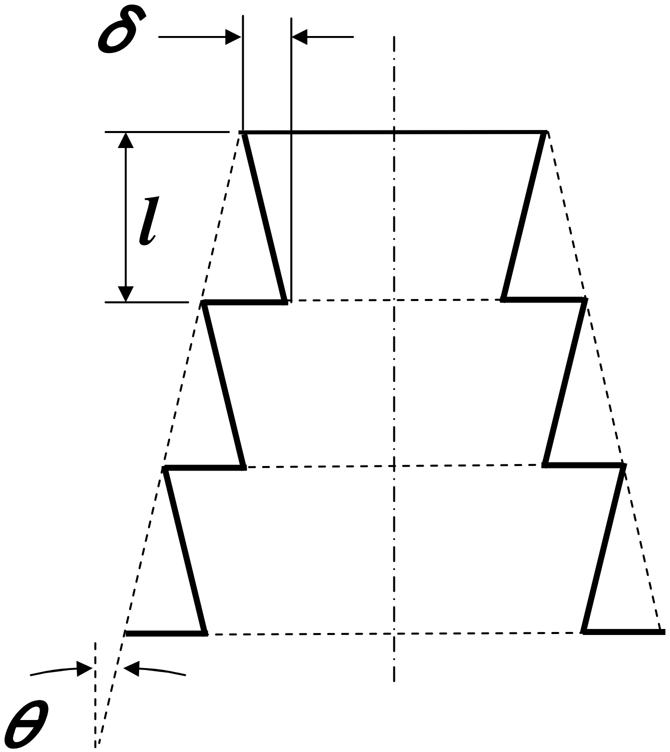


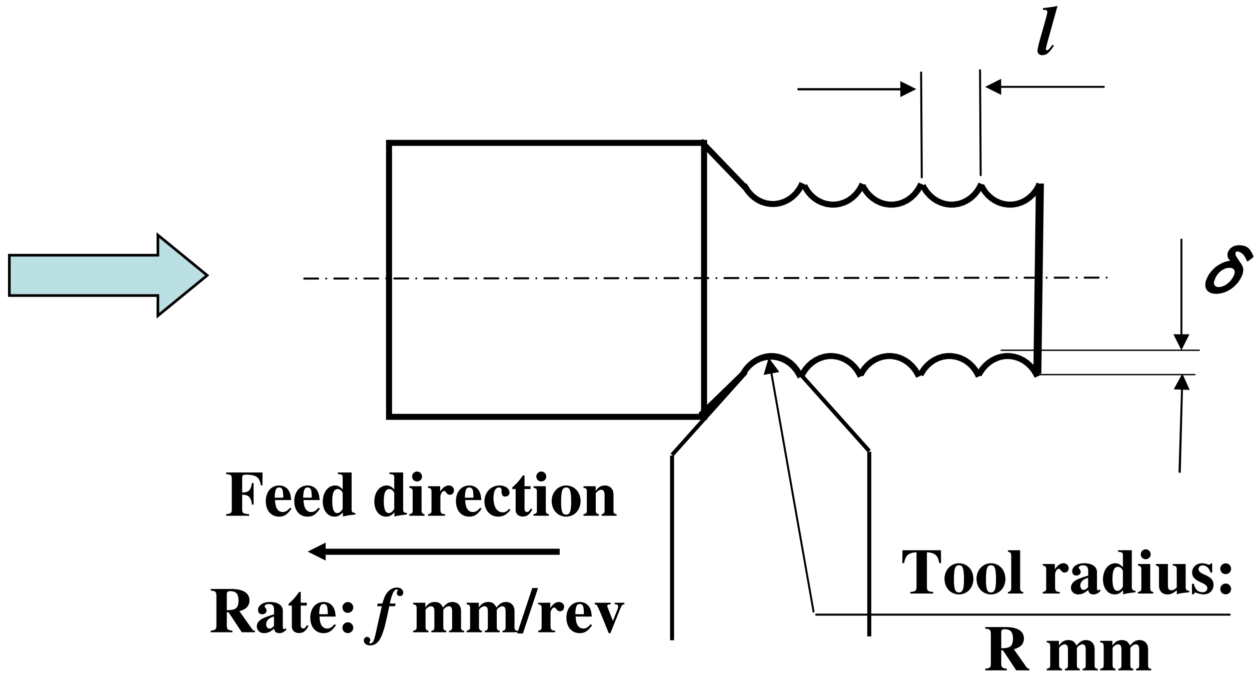
Stereolithographic,
stair-step profile

?

Turned periodic mould
surface profile

Analogy between stereolithographic and periodic (turned) surface - 1

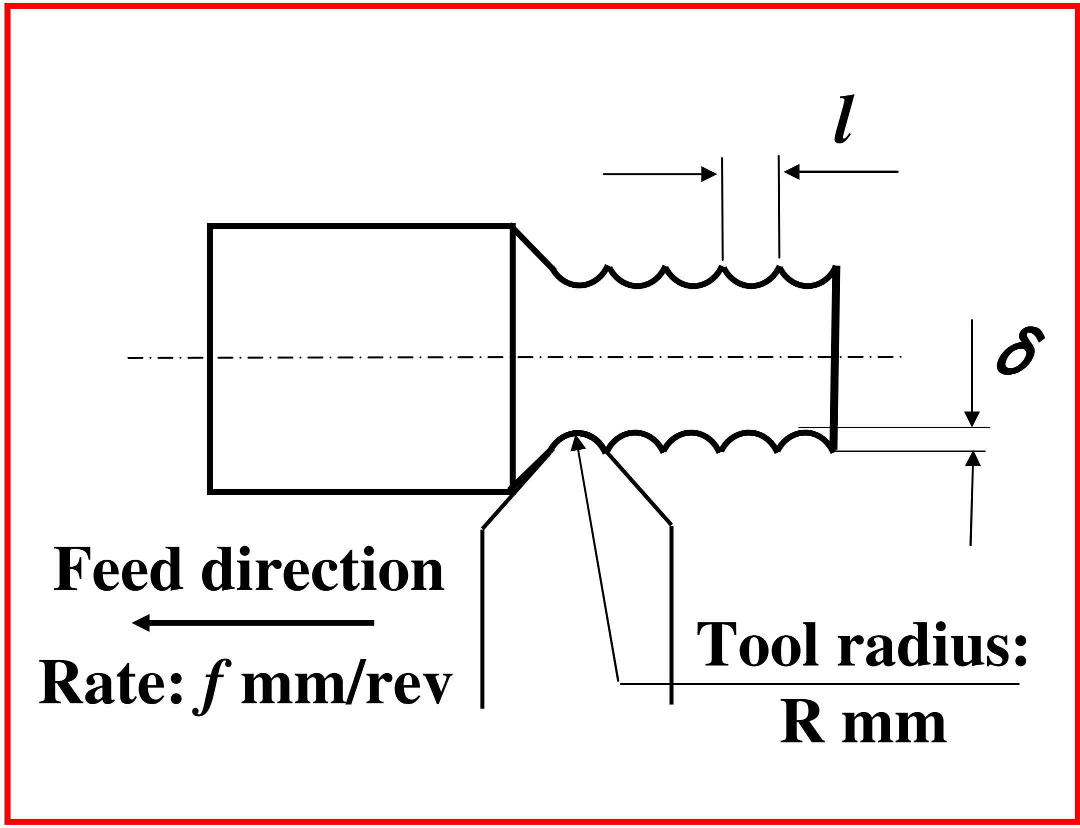




Stereolithographic, stair-step profile

Turned periodic mould surface profile

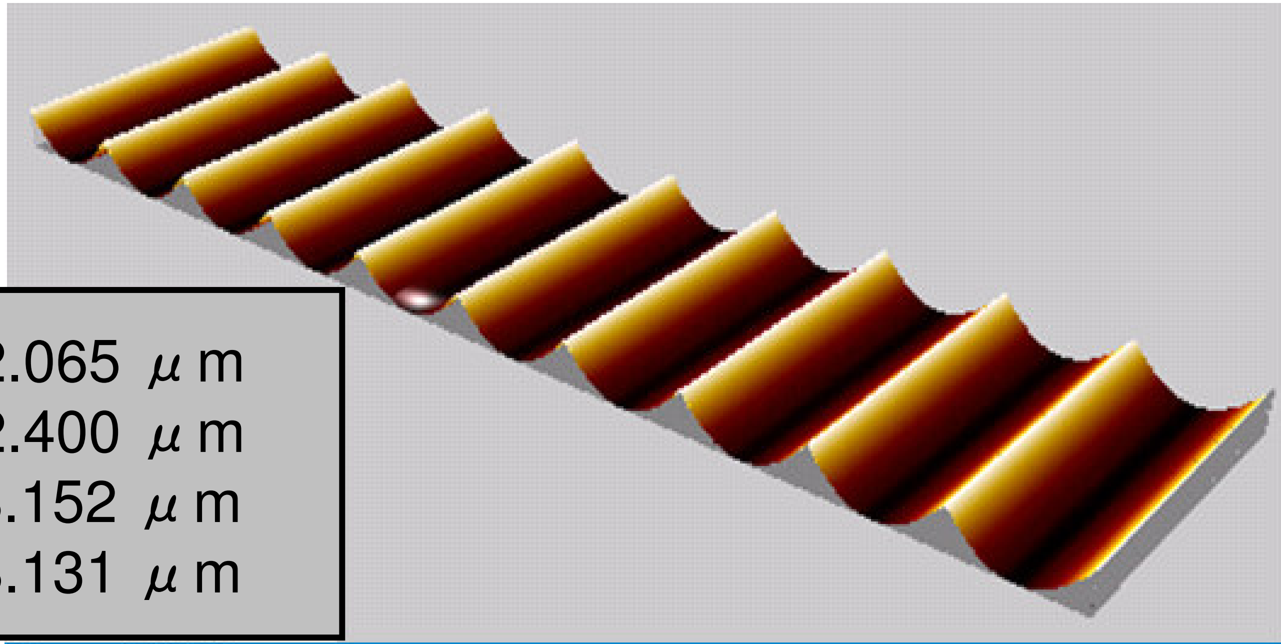
Analogy between stereolithographic and periodic (turned) surface - 2



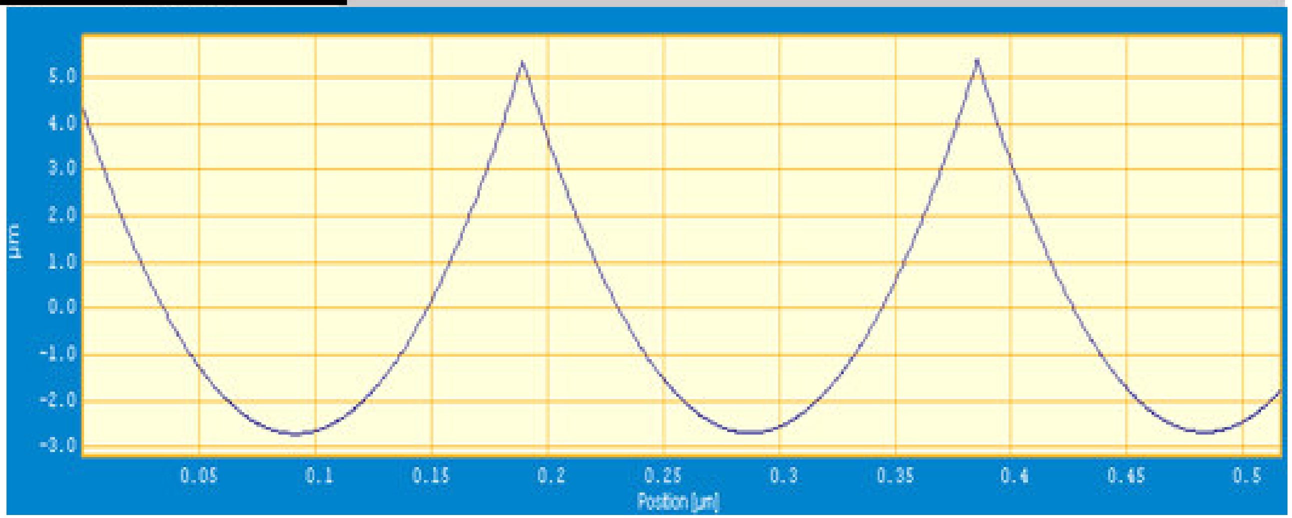
$$Ra = \frac{f^2}{32 \times R}$$

$$\delta = \frac{f^2}{8 \times R}$$

Surface simulation and analysis for verification

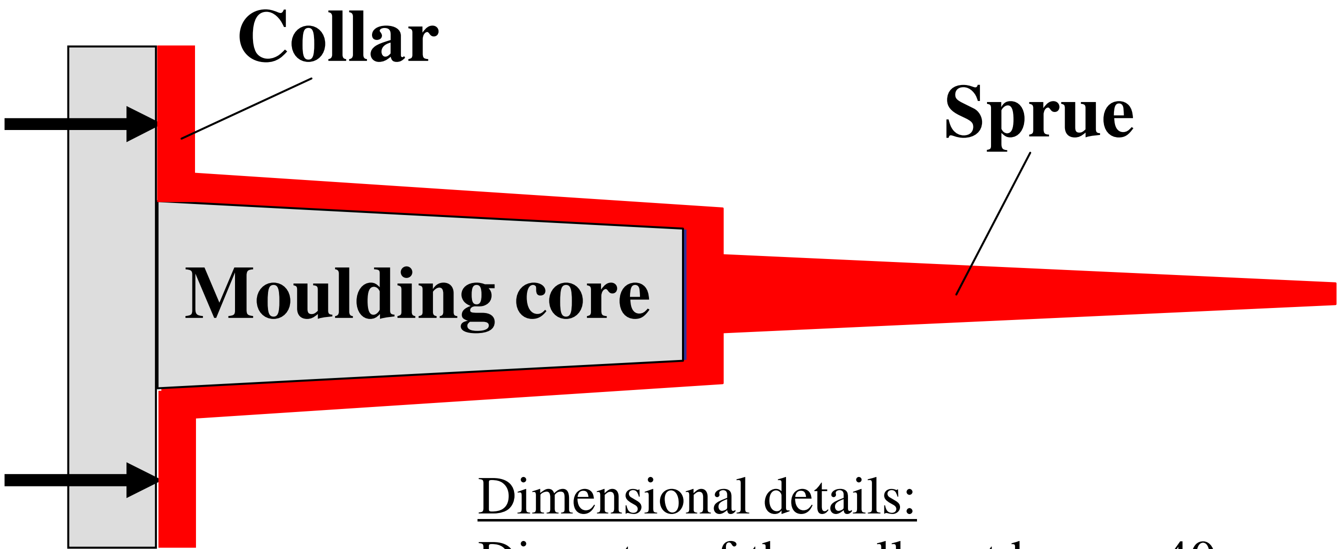


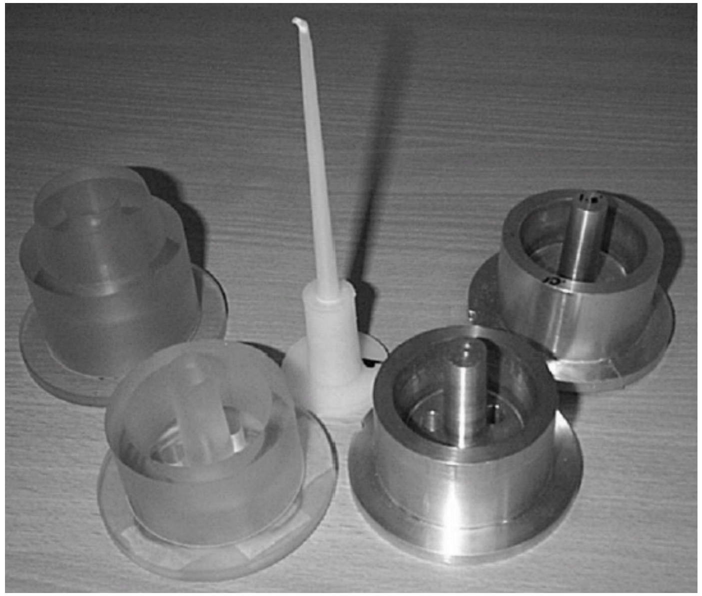
Sa	2.065	μm
Sq	2.400	μm
Sy	8.152	μm
Sz	8.131	μm



Model implementation

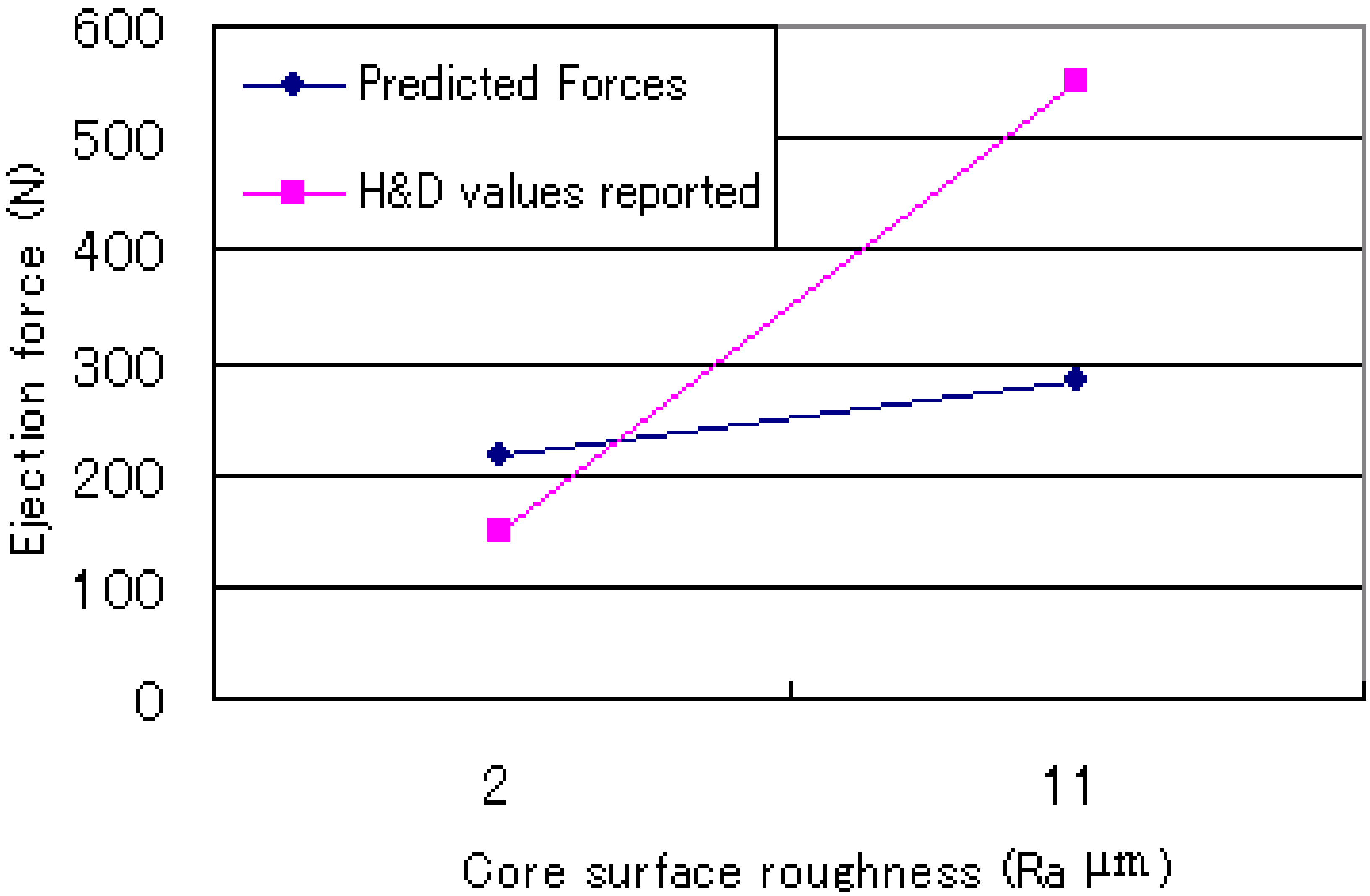
Details of Hopkinson and Dickens component used for validation





Dimensional details:
Diameter of the collar at base = 40mm,
Diameter at opening of collar = 16mm,
Length of the moulding = 40mm,
All walls 2mm thick,
Draft on male feature = 1.5 degrees.

Model validation



Robustness of the Colton et al Model - 1

Parameter		Value
Cutting tool radius (mm)	R	0.2 ~1.0
Mould temperature at ejection (° C)	T_{me}	30 ~ 60
Mould temperature at injection (° C)	T_{mi}	15 ~ 49
Component ejection temperature (° C)	T_{pe}	40 ~ 60
Polymer melting temperature (° C)	T_{pm}	160 ~ 173
Coefficient of friction	μ	0.25 ~ 0.4

Robustness of the Colton et al Model - 1

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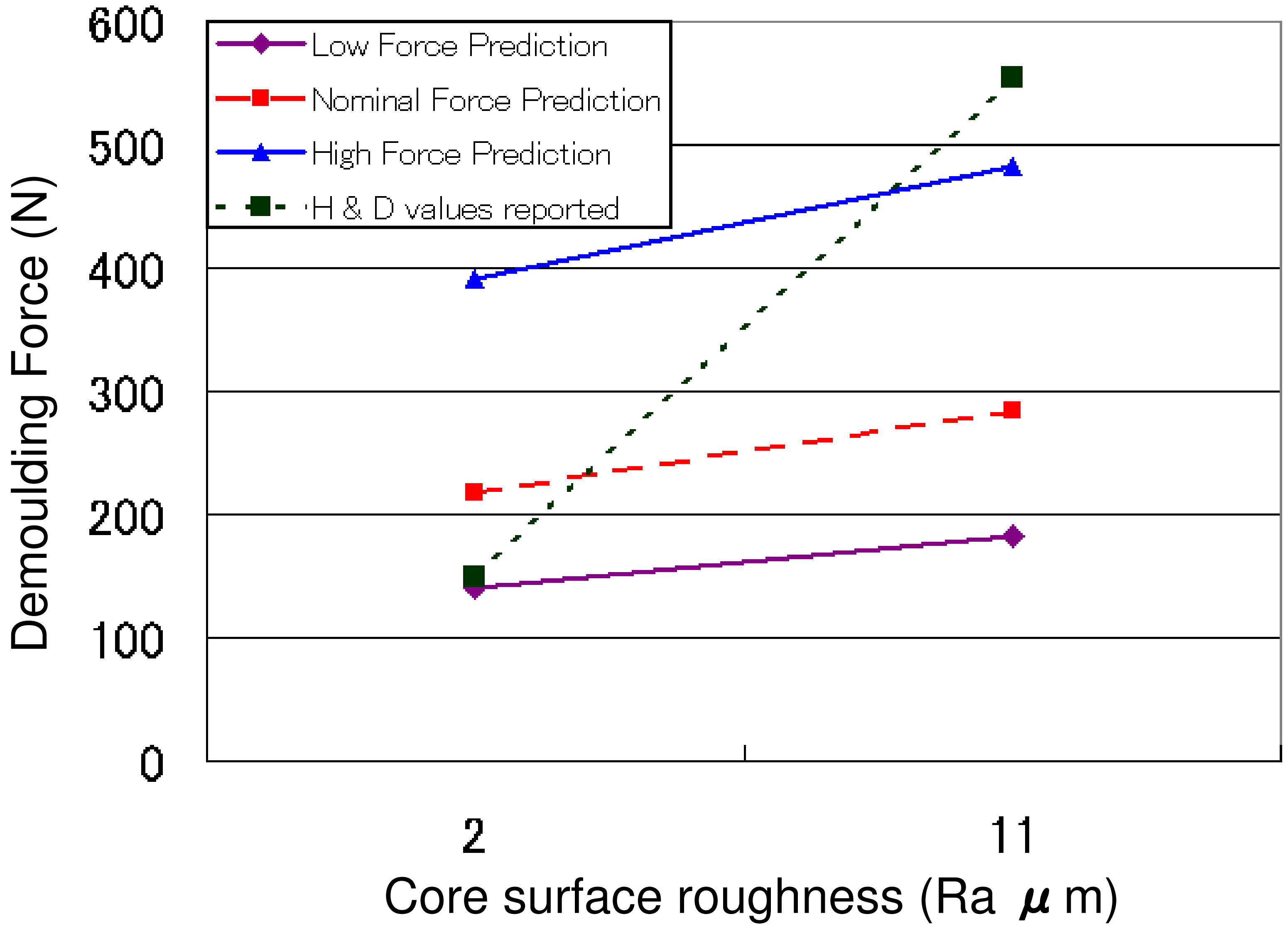
Robustness of the Colton et al Model - 2



Conclusion

- Limitations of the Colton et al model applied to periodic (non stereo-lithographic) surfaces highlighted.
- Some issues related to micro machined surfaces listed.
- More advanced model needed
  – Should consider viscoelastic behaviour of replicating material together with any permanent deformation (instead of assuming elastic deformation).
- Model should be suitable for implementation in a Finite Element Modelling package.
- Efforts are ongoing towards the development of such a model.

Questions?

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